Central Phoenix / East Valley Light Rail Project

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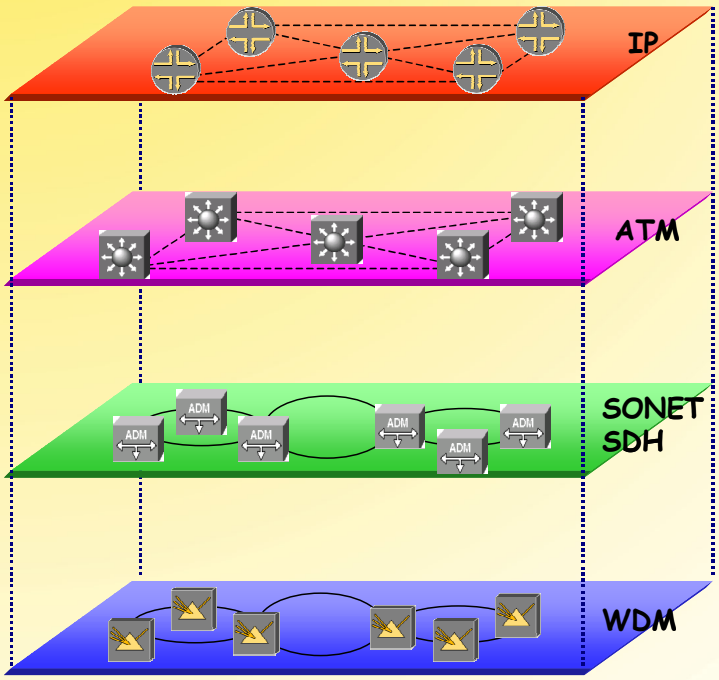
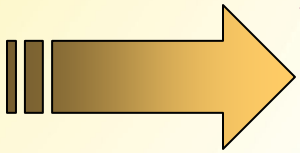
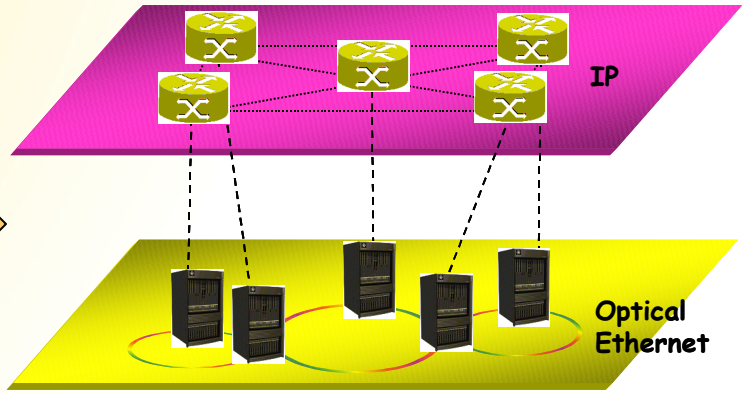
Vision

The Metro is Transitioning







Optical Ethernet:

- ✓ **Traffic engineering**
- ✓ **Transport / protection**
- ✓ **Integrated DWDM for scalability**
- ✓ **Layer 2 services**

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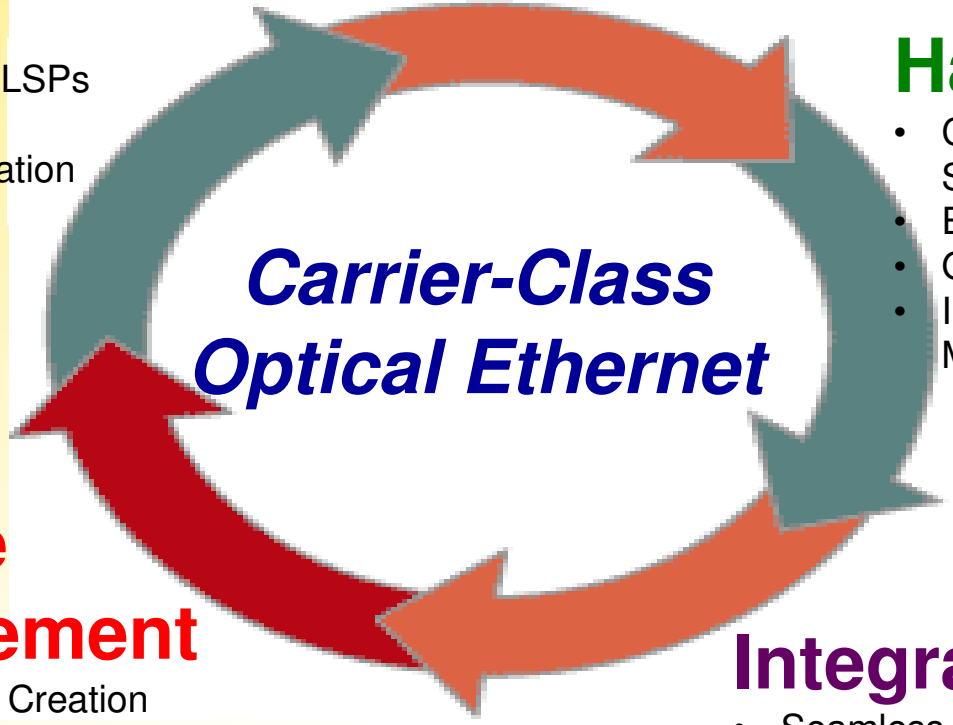
Protection

- 50ms Protection
- No Spanning Tree
- MPLS Fast Reroute

Scalable

- No VLAN Limitation
- Services Mapped to LSPs
- Optical Integration
- Flexible Service Creation



Carrier-Class Optical Ethernet

Hard SLAs

- Connection Oriented Services
- End-to-End CIR and EIR
- Guaranteed End-to-End SLA
- Integrated Customer Network Management (CNM)

Service Management

- Fast Service Creation
- Integrated Third Party Management
- Customer Network Management (CNM)
- Carrier -class OAM Capabilities

Integrated TDM

- Seamless Integration of TDM
- Supports Existing Voice Applications
- Tested and Proven with Large ILECs

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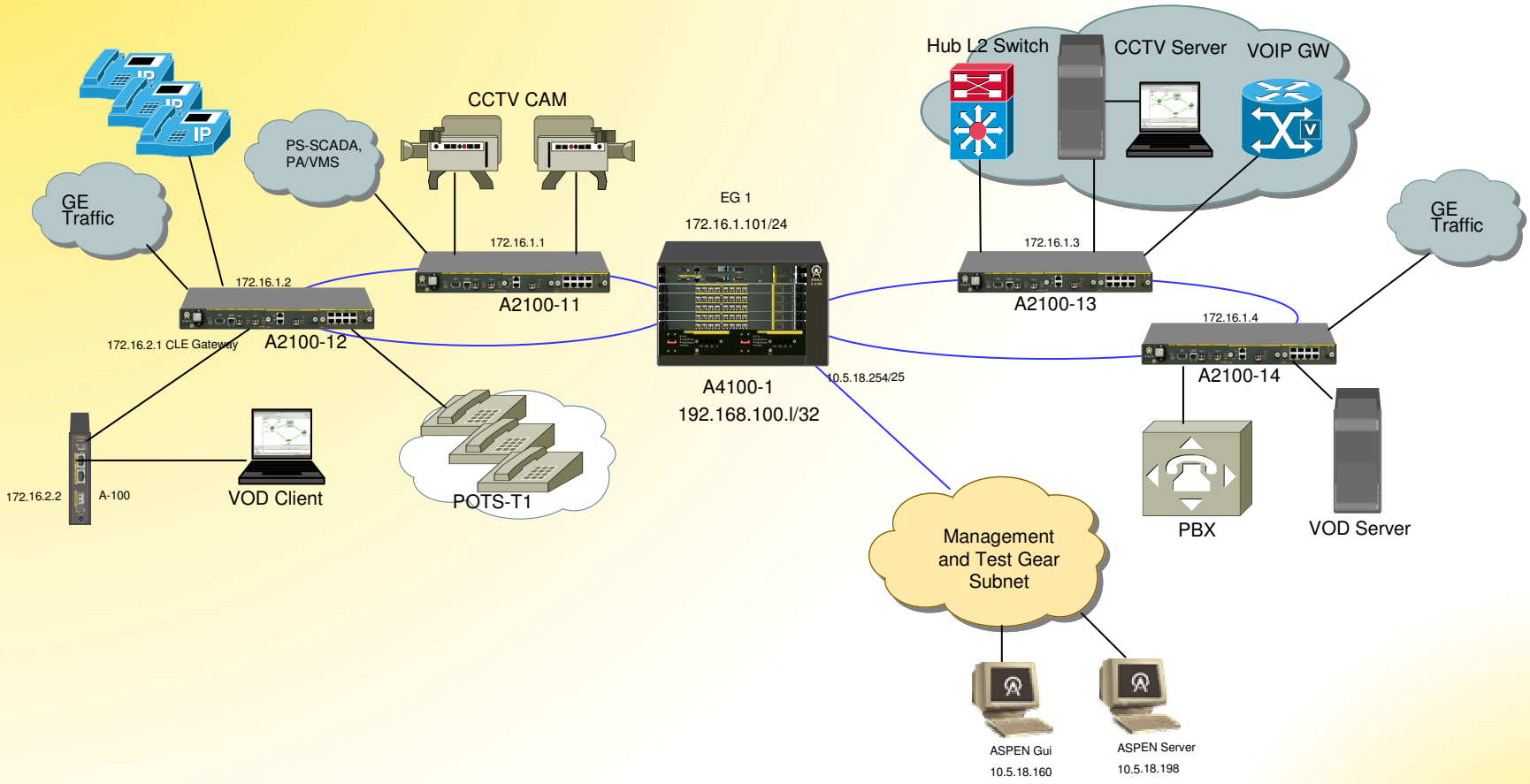
GE Transportation Trial Layout



Legend

GE

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Product Overview

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A-4100 Metro Aggregation Product Highlights

- 80 Gb/s wire rate switching capacity
  - 8 slot chassis
    - 2 redundant switch cards
    - 6 interface cards
- Dual Power Supply – DC
- 1:N Multiple FAN Assembly
- Full serviceability from front side
- Sub-50ms Protection
  - Link and Node per service
  - SWC and IFC
- Pluggable Interface modules
  - Same modules used for A-8100 series switches
  - 8 port Gigabit Ethernet module
  - 1 port 10 Gigabit Ethernet module
- Hard QOS Architecture
  - Strict BW guarantees per service
  - Bounded Delay and Jitter
- Service Delivery
  - PTP (Ethernet Virtual Circuit
  - MPMP (ELAN service enabler)
  - PTMP (Mulitcast)

A-4100

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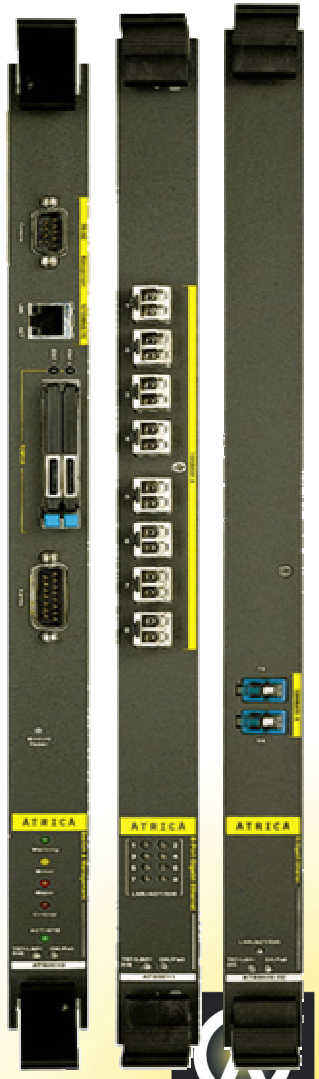
A-4100/A-8100 Modules

- Switch and Management Module
  - Two types
    - 150Gbps for A-8100
    - 80Gbps for A-4100
  - Front Panel:
    - Interfaces:10/100 Management, RS232 Console, Dry Contact
    - 2 PCMCIA Slots
    - LEDs: System status & Alarm
- 8 Port GE Module
  - Physical interfaces:
    - 8 SFP GbE ports
    - Supported SFP optics: 10/40/70/120Km, CWDM, SSF
  - Logical Interfaces:
    - User Edge, Network Edge, Network Core
  - Ingress/egress Packet Processing, QoS and SLA enforcement
  - Supports up to 8K Connections
- 10 GbE Module
  - Supports up to 8K Connections
  - 10GE Standard Remote Alarm Indication
  - Interface types: (Class 1 laser safety)
    - 1310nm 10km & 40km ; 1550nm 40km & 70km both w/E-2000 connector
    - XFP based
    - 15xx DWDM 100Ghz, ITU grid



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A-2140 Series
Carrier Ethernet Edge/Access

- 1U modular high-performance switch
  - 2 x 1GE Network Ports
  - 4k VLANs, 2K protected connections
- Various access modules:
  - Ethernet: GE, 24FE, 8FE, 8FX
  - CES: T1/E1, STM-1/OC-3
- Carrier class platform
  - 50mSec protection
  - AC and DC power supplies
  - Redundant power
  - Dry Contacts w/input relays
- Carrier class OA&M
  - Statistics and alarm collections
  - Delay and jitter measurements
  - Loopback functionality for fault isolation

A-2140

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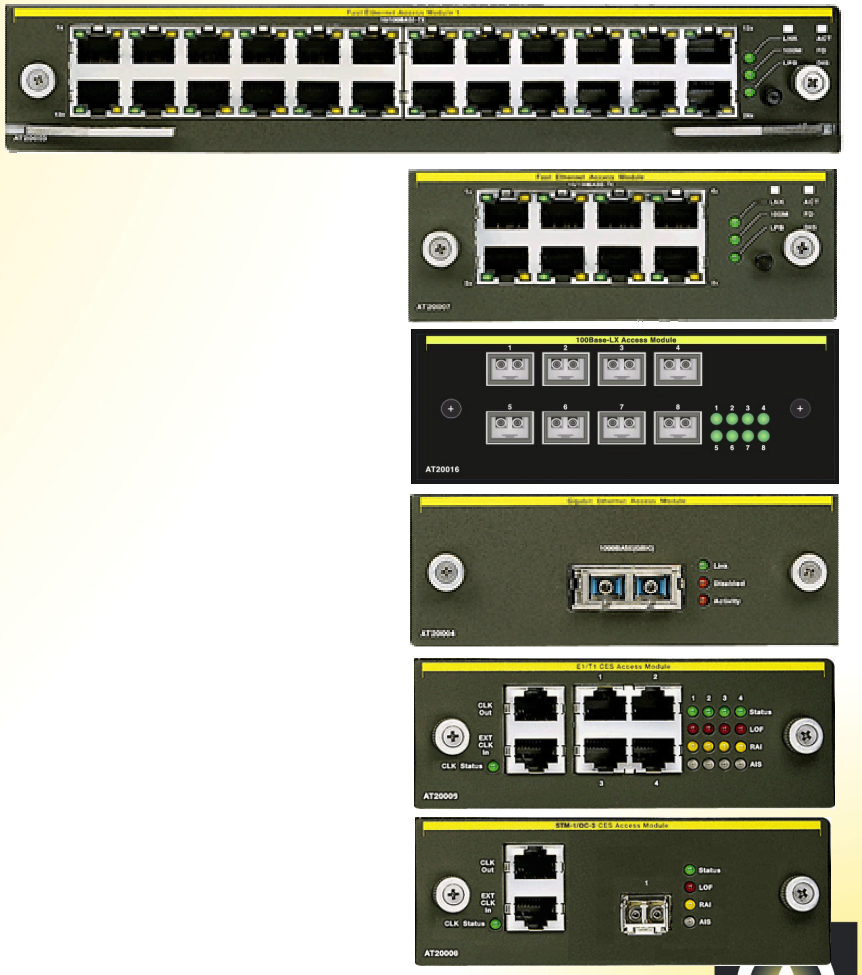
A-2100/A-2140 Access Modules

- 24xFE TX
- 8xFE TX
- 8xFE FX 10Km
- 8xFE FX 40Km
- 8xFE SSF 20Km
- 8xFE SSF 40Km
- 1xGE (GBIC)
- 4xE1/T1 (CES)
- 1xSTM-1/OC-3 (CES)



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RPR and Carrier Class Ethernet

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RPR and Atrica Carrier Class Ethernet

- *Technology Introduction*
- *Connection Orientation*
- *Protection*
- *QOS*
- *OAM*
- *Scalability*
- *Standardizations*

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RPR and Atrica Carrier Class Ethernet

Technology Intro

- *RPR provides statistical multiplexing gains for Sonet*
- *Ethernet application provides for sub-50ms protection*
- *Carry TDM and Data*
- *Fairness Algorithms defeat starvation issues on shared rings*
- *Buffering/backpressure mechanisms provide for limited SLA adherence.*
- *RPRs benefits cannot extend passed the ring therefore its best use is in the access ring of the metro-wide network.*

- *Atrica CCE provides an architecture to construct Data and TDM networks from Native Ethernet.*
- *Sub-50ms protection at the network and equipment levels*
- *Hard QOS providing stringent SLA delivery capabilities*
- *Bandwidth Reclamation, reuse of dedicated BW and protection paths*
- *Scalable across any topology- virtual or physical*

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RPR and Atrica Carrier Class Ethernet

Connection Orientation

- *RPR is not Connection Oriented.*
- *Soft QOS*
- *Limits topology to Ring Only*
- *All RPR benefits are negated after traffic egresses ring*
  - *Unable to guarantee QOS across rings*
- *Requires MPLS + RPR to provide TE, BW control, and end to end QOS*
- *RPRs primary strengths are duplicated with addition of MPLS so the question is why use RPR for MAC layer arbitration?*

- *Atrica CCE is Connection Oriented.*
- *Hard QOS*
- *No topology restrictions*
- *All SLA parms are supported over all topologies including protection, CIR/EIR and bounded D&J.*
- *Based on Tag switching technologies such as MPLS*
- *Ethernet natively provides spatial reuse and asynchronous operation including statistical muxing. MPLS strengthens this with fairness mechanisms, protection enhancements, enablers for hard QOS, etc.*

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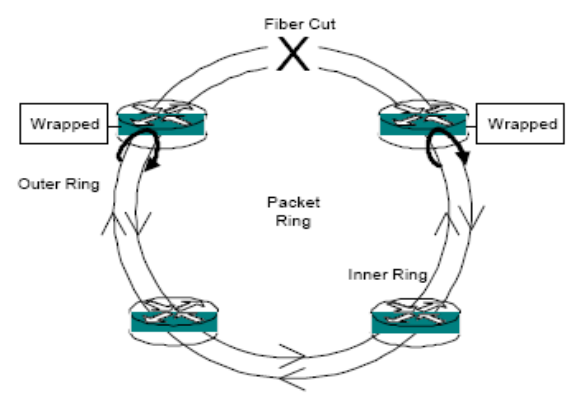
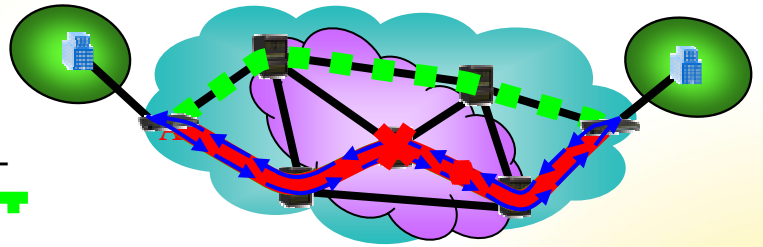
RPR and Atrica Carrier Class Ethernet

- Protection
  - RPR provides sub-50ms protection for Node and Link using steer and wrap techniques in the access ring only.



  - Atrica CCE provides sub-50ms failure for Node, Link, SWC/Mngt. Module, and I/F cards for all topologies
    - 2 level protection mechanism
      - End-to-End-OAM path availability-topology optimization
      - Fast reroute for node and link



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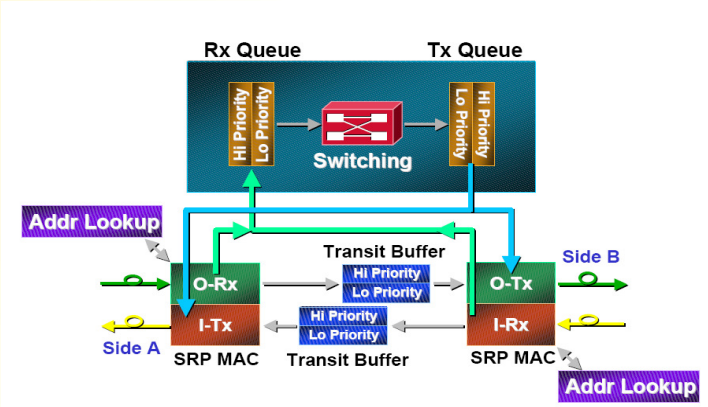
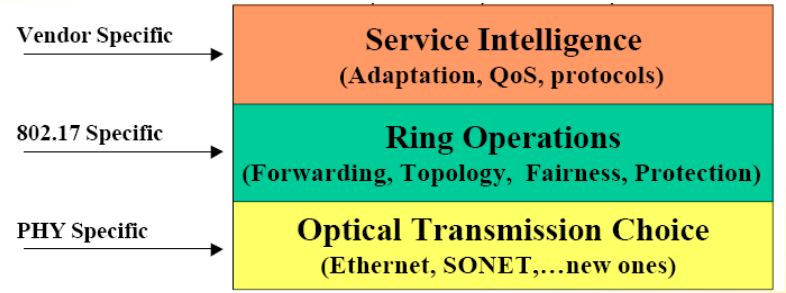
RPR and Atrica Carrier Class Ethernet

- RPR QOS
  - Is not a connection oriented architecture
  - 802.17 does not specify QOS capabilities. This is proprietary
  - Supports 3 priorities for ring arbitration
    - HP-bounded b/w, delay, jitter.
      - CES/Video
      - No burst
    - MP-CIR/EIR subject to Discard by Fairness Alg.
    - LP-BE
  - Requires soft QOS capabilites (p-bits, DSCP) classification at each hop
  - Applies only to local RPR ring. Services that travel off the ring are subject to QOS of core layer.
  - No reuse of protection paths
  - Spatial Reuse
  - FA for fair arbitration of DE and BE services





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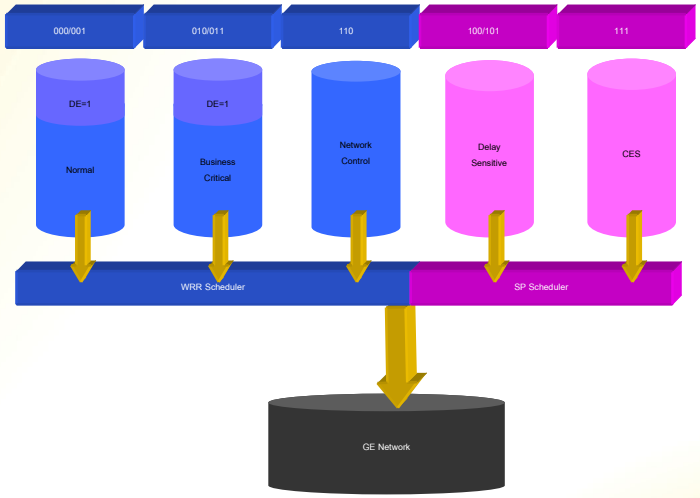
RPR and Atrica Carrier Class Ethernet

- Atrica CCE QOS
  - Connection oriented
  - Classify on VLAN, Tagged, untagged, Ethertype, Pbit, dscp, IP source or dest, UDP, TCP, ARP, Protocol
  - Call Admission and Control (CAC)
  - TED
  - 5 Queues controlling bounded Delay&Jitter w/hybrid scheduler
    - CIR/EIR with DE
  - Spatial Reuse
    - Reuse of protection paths
    - Committed BW returned to BE and EIR services when not in use
  - Protection paths are reserved but not used



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RPR and Atrica Carrier Class Ethernet

- RPR OA&M
  - On-demand in-service loop-back mechanism (echo request/response) is used for troubleshooting the RPR network
  - Continuity check (CC) is used for fault detection by continuously running and warning the operator when a failure occurs
  - Remote defect indication (RDI) is used together with the CC mechanism to inform the source node of a flow that the destination node has detected a failure on that flow
  - Activation/deactivation of the CC functionality, is used to coordinate the beginning or end of the transmission and reception of CC.
    Currently, support for the loop-back mechanism is mandated by the draft standard, while support for the continuity check mechanism (and its related RDI and activation/deactivation frames) is optional.

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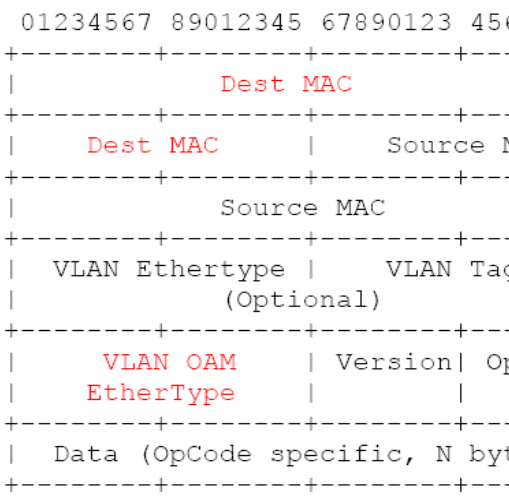
RPR and Atrica Carrier Class Ethernet

- CCE OA&M
  - Defined and standardized by MEF
    - Four primary functions
      - Discovery
      - Path Integrity
      - Latency and Loss Measurement
      - Jitter Measurement
  - Atrica additions
    - Ethernet Loopback
    - Historical reporting for Availability/Packet Discard/Delay/Jitter/Etc. with Threshold Alarms
    - RT D&J tests from NMS/CLI
    - Path integrity
    - End to end protection
    - Flow statistics for Path availability via NMS

OAM Frame



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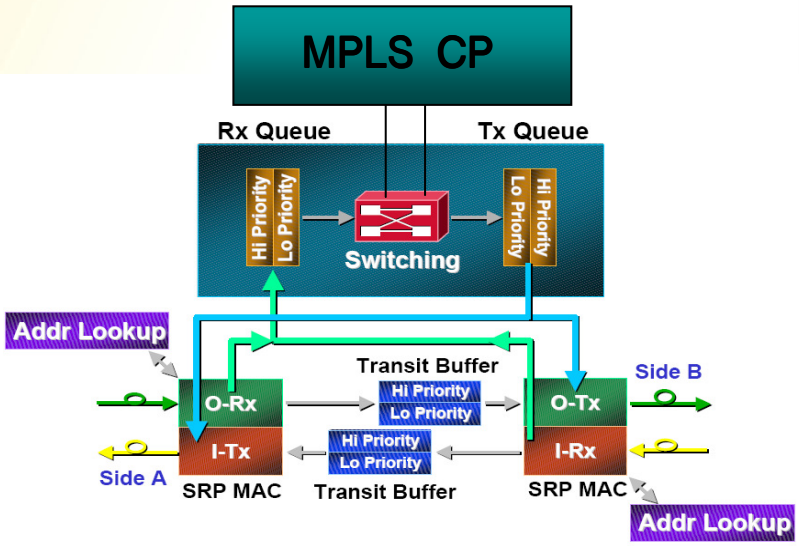
RPR and Atrica Carrier Class Ethernet

- Scalability
  - RPR
    - 255 nodes per ring due to drop and insert capabilities *(fast path)*
    - Scales in access ring but not metro scope- requires MPLS to scale effectively over multi-ring or partial/full Mesh
    - Adding MPLS CP to the RPR architecture severely effects scalability since fast path is not longer a valid transit path
    - Natively RPR cannot scale incrementally
  - Atrica CCE
    - 32 nodes per ring-2G
    - Fast path capabilities
    - 2000 services per A-2100 platform
    - Can scale to millions of core MPLS connections
    - No dynamic signaling
    - ASPEN provides quick and easy provisioning over large networks insure SLA adherence
    - Connection Or. Allows incremental scaling over additional fiber, topologies, CWDM, or DWDM



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RPR and Atrica Carrier Class Ethernet

- RPR Standardizations
  - DPT (Cisco proprietary)
  - SRP
  - RPR standardized by 802.17
    - Support for dual counter rotating ring topology
    - Full compatibility with IEEE's 802 architecture as well as 802.1D, 802.1Q and 802.1f
    - Protection mechanism with sub 50ms fail-over
    - Destination stripping of packets
    - Adoption of existing physical layer bmedium to avoid technical risk.

- CCE Standardizations
  - MEF
    - Build consensus and unite service providers, equipment vendors and end-customers on Ethernet service definition, technical specifications and interoperability.
    - Facilitate implementation of existing and new standards, Ethernet service definition, test procedures and technical specifications of the MEF to allow delivery of Ethernet services and make Ethernet-based metro networks carrier-class.
    - Enhance worldwide awareness of the benefits of Ethernet services and Ethernet-based metro transport networks.

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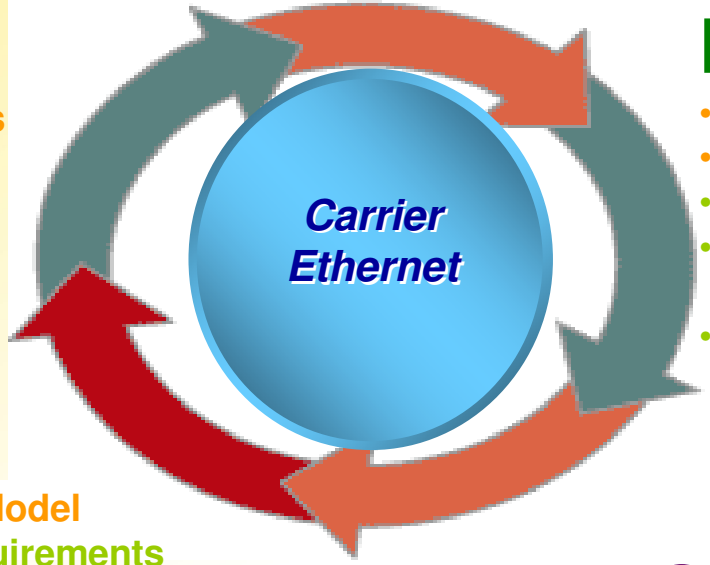
Carrier Class Ethernet Standards

Reliability

- MEF 2 – Ethernet Protection
- MEF 4 – Architecture Framework
- MEF Service Attributes II
- IETF – MPLS Fast Reroute

Scalability

- MEF 4 – Architecture Framework
- MEF 12 – Eth Layer Architecture
- MEF 6 – Service Definition
- MEF 11 – UNI Framework
- MEF 9 – UNI Testing
- MEF 10 – Service Attributes
- MEF UNI I IA
- MEF UNI Type II
- MEF Ethernet Aggregation
- IEEE 802.1, IETF



Hard QoS

- MEF 6 – Service Definition
- MEF 10 – Service Attributes
- MEF Service Attributes II
- MEF Service Attributes Testing
- MEF Service Definition II

Service Management

- MEF 7 – EMS and NMS Info Model
- MEF OAM Framework & Requirements
- MEF E-LMI
- MEF Performance Monitoring
- MEF NE Management Requirements
- IEEE 802.1, ITU

TDM Support

- MEF 3 – CES Framework
- MEF 8 – CES Implementation
- MEF TDM Testing

METRO Ethernet Forum

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Design Overview

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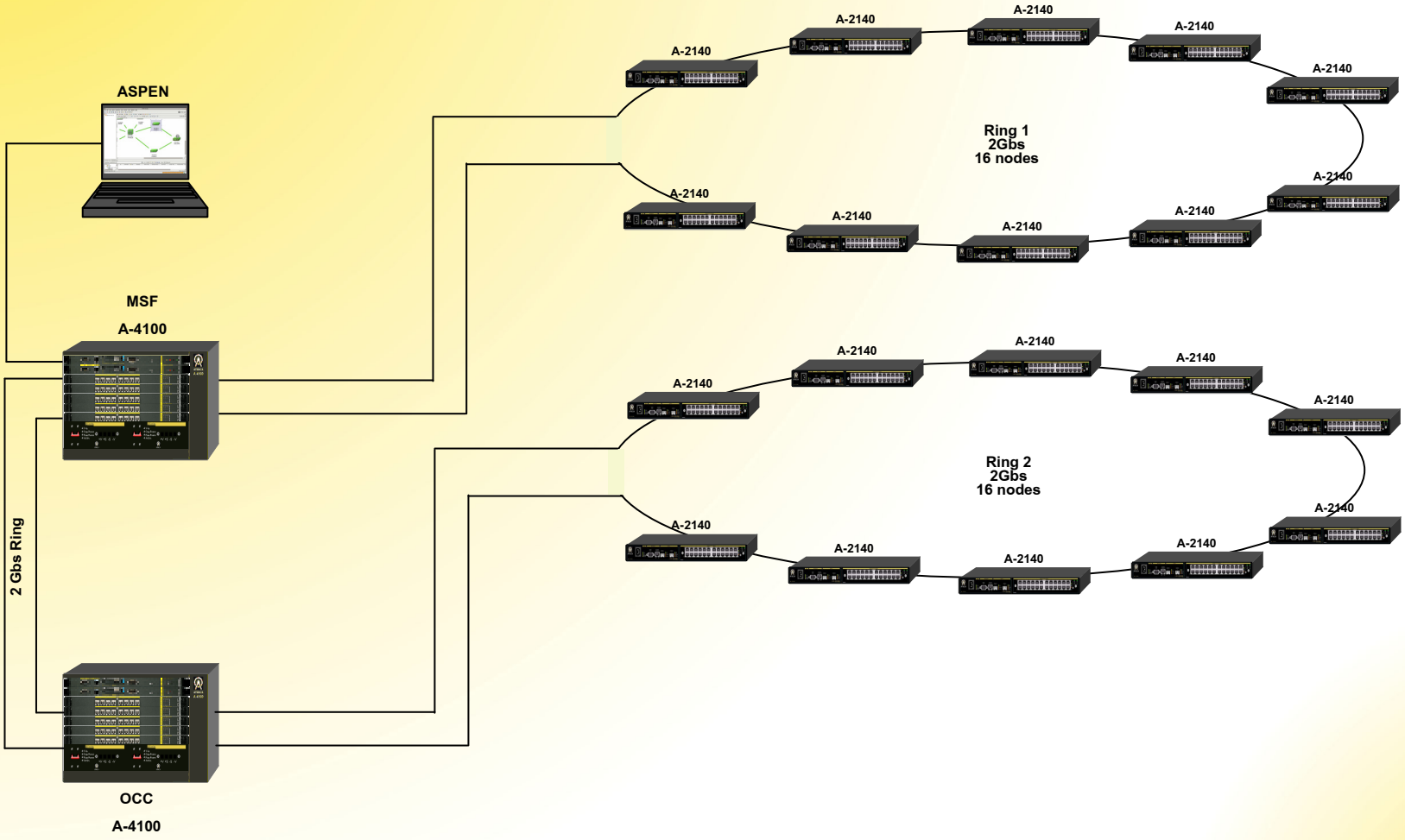
Network Overview



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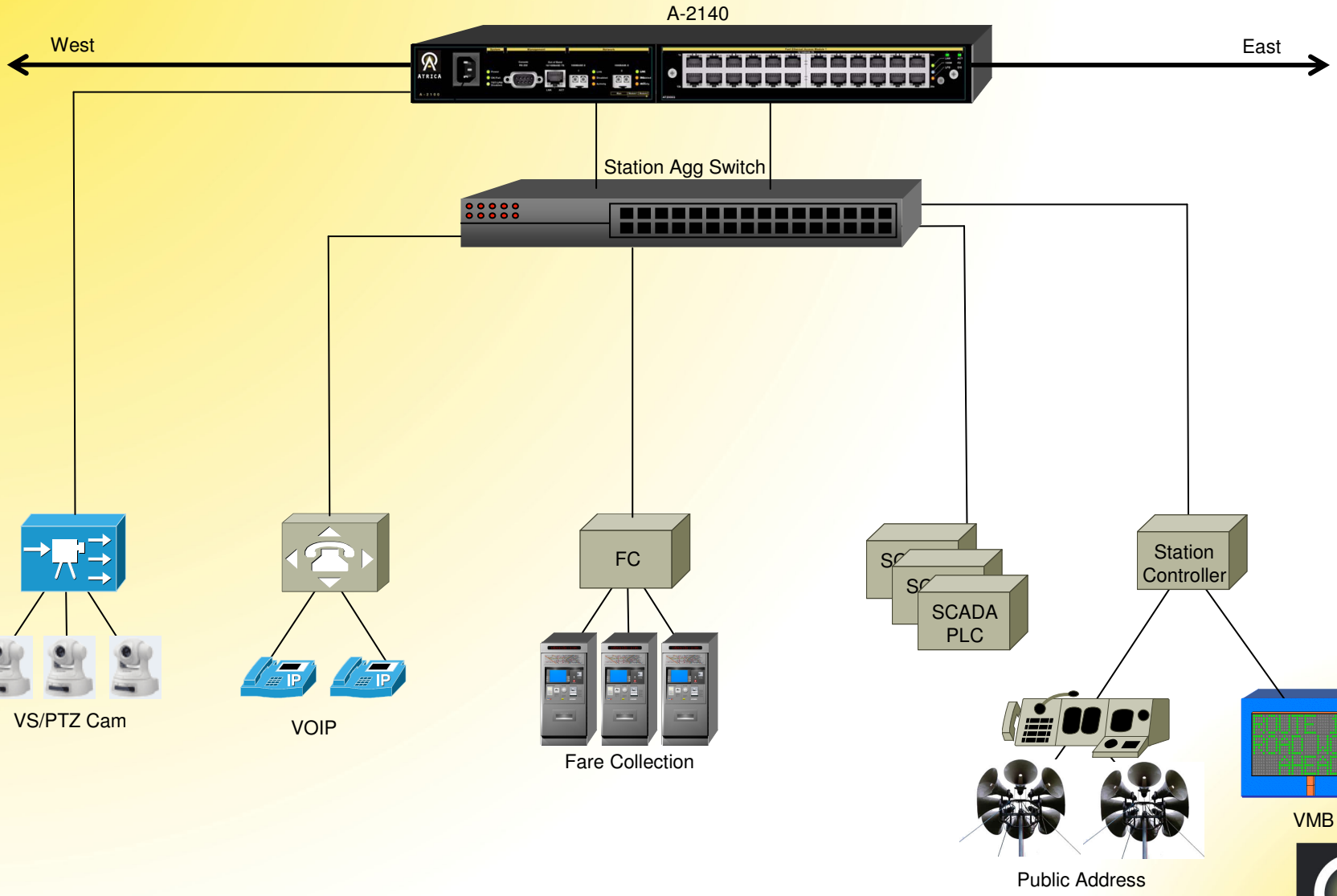
Passenger Station



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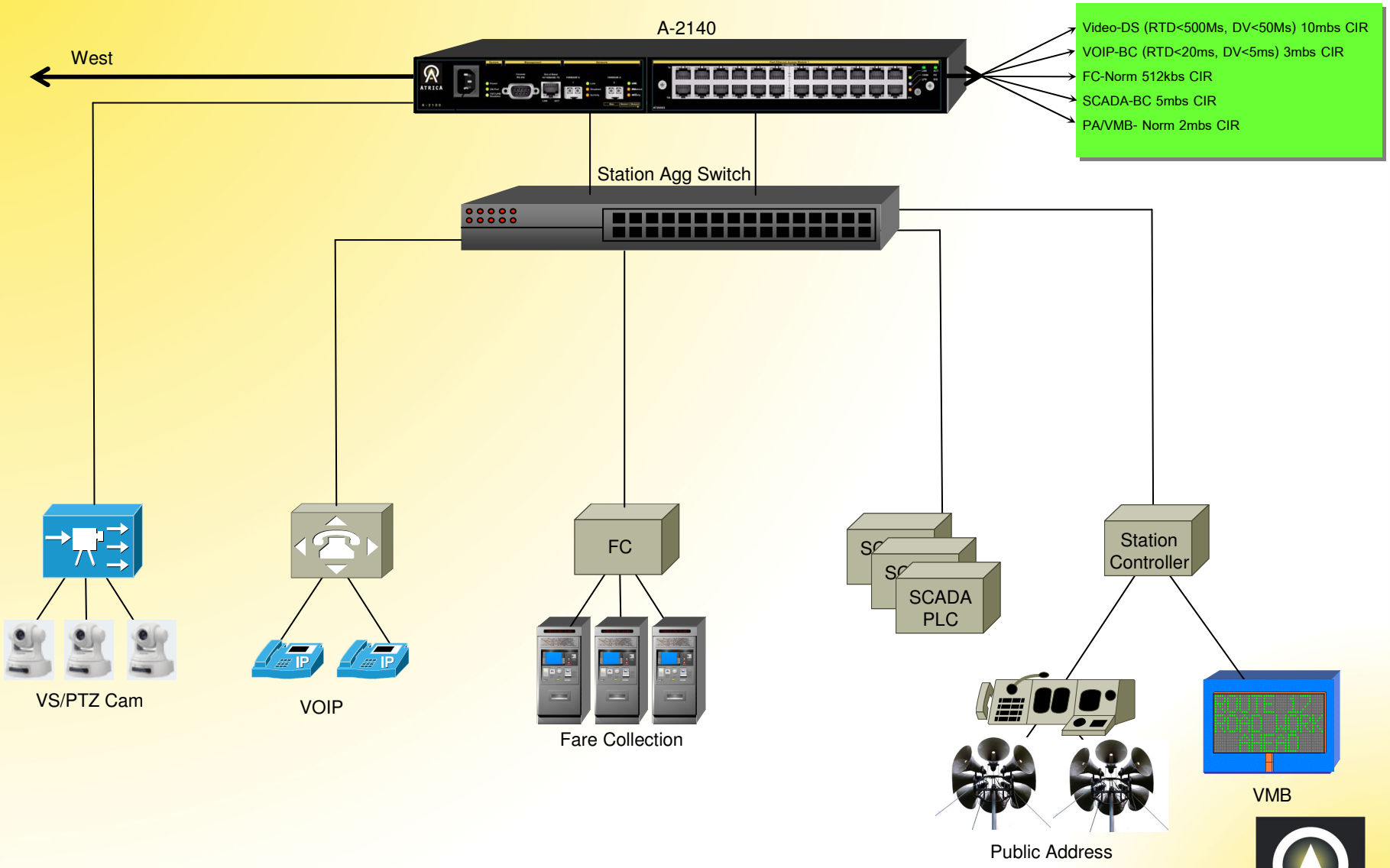
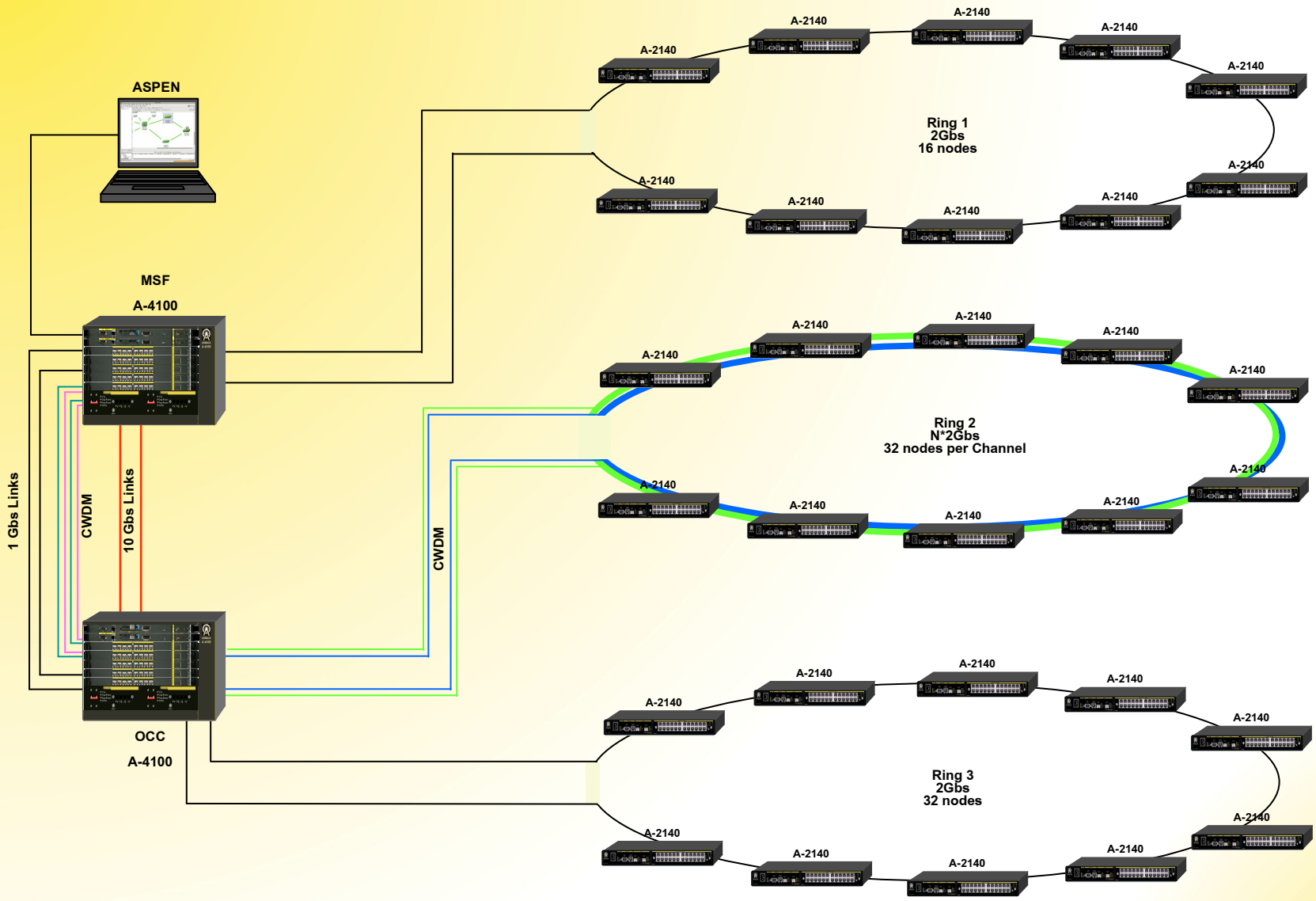
Passenger Station



Network Scalability



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